Future of CCS Technology Adoption at Existing PC Plants

CO_2 Capture Technology Meeting—Pittsburgh, PA

Oxy-combustion—Wednesday, August 24, 2011

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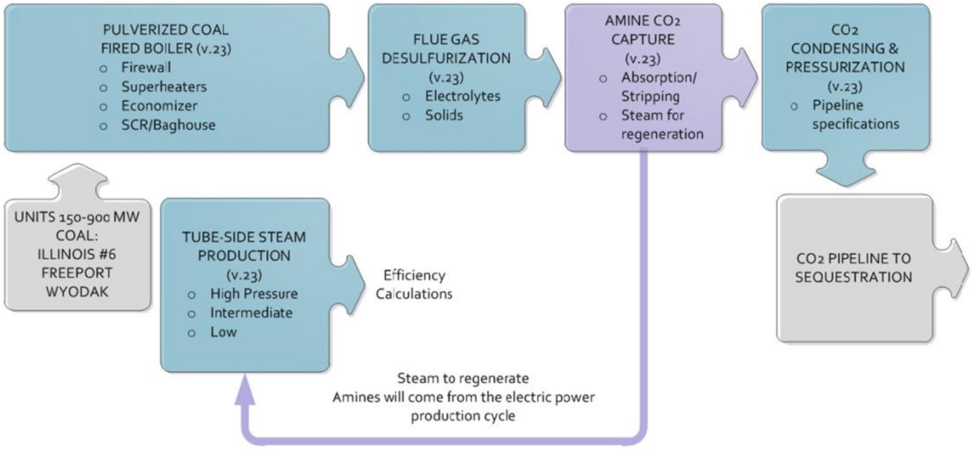
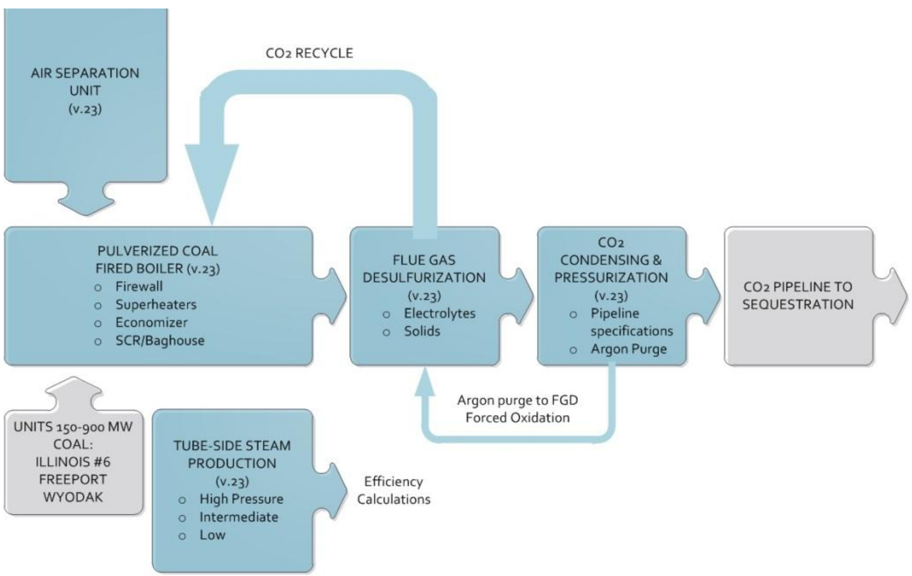
Funding and Project Performance Dates

- FY2011 Funding: $275K
- Project funds remaining: $130K
- ASPEN Simulation Methodology and Results
  - Oxyfuels Report: November 2011
  - AMINES Report: November 2011
- Existing PC Plant CCS Retrofit Scenarios
  - EERC Air Quality conference paper, Washington DC, October 24-27
  - Interim draft report: November 2011
  - Final Report: March 2012

PC-boiler retrofit for Amines and Oxyfuels

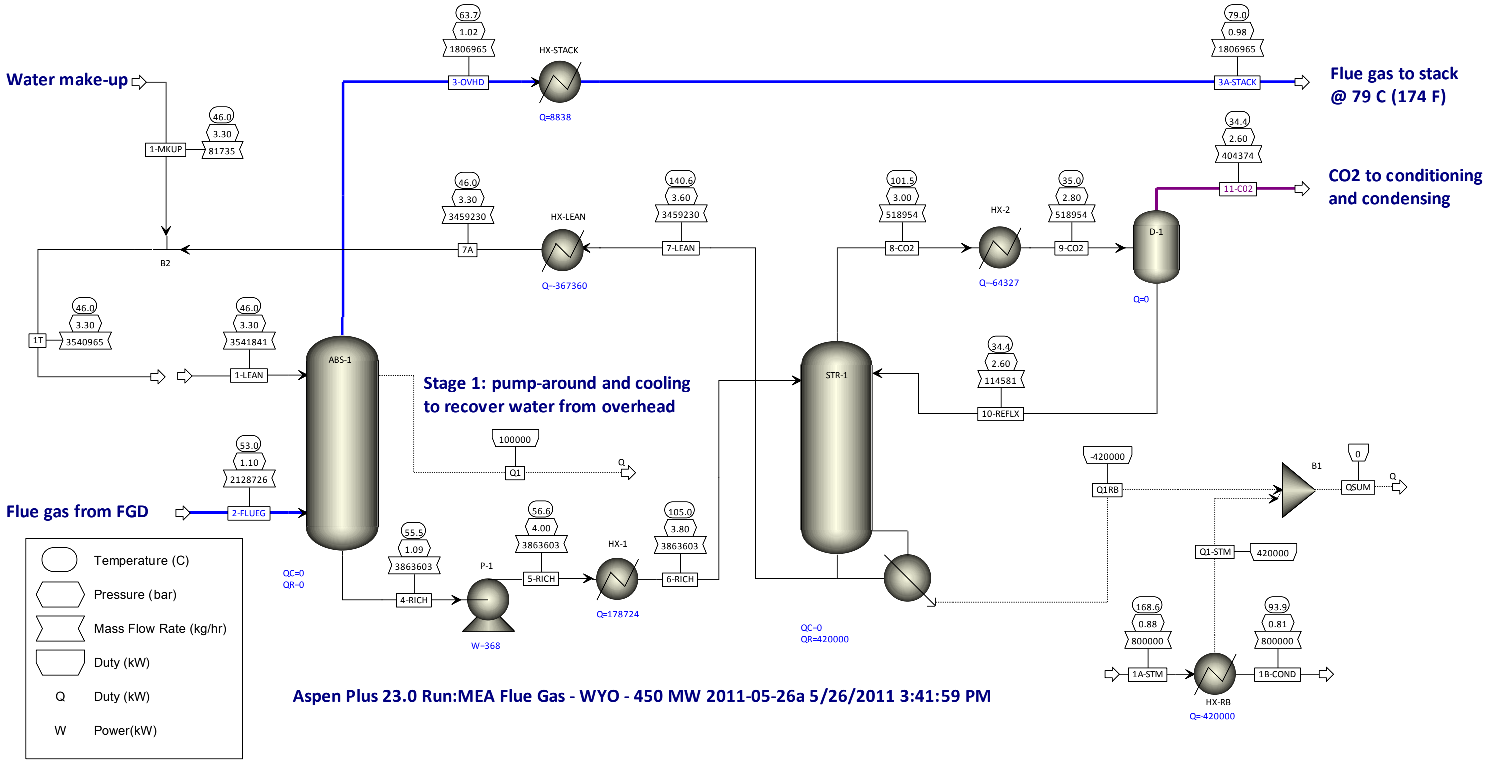


DEA & MEA System models were developed. retrofitting impacts the steam-to-electricity; FGD; and CO_2 condensing



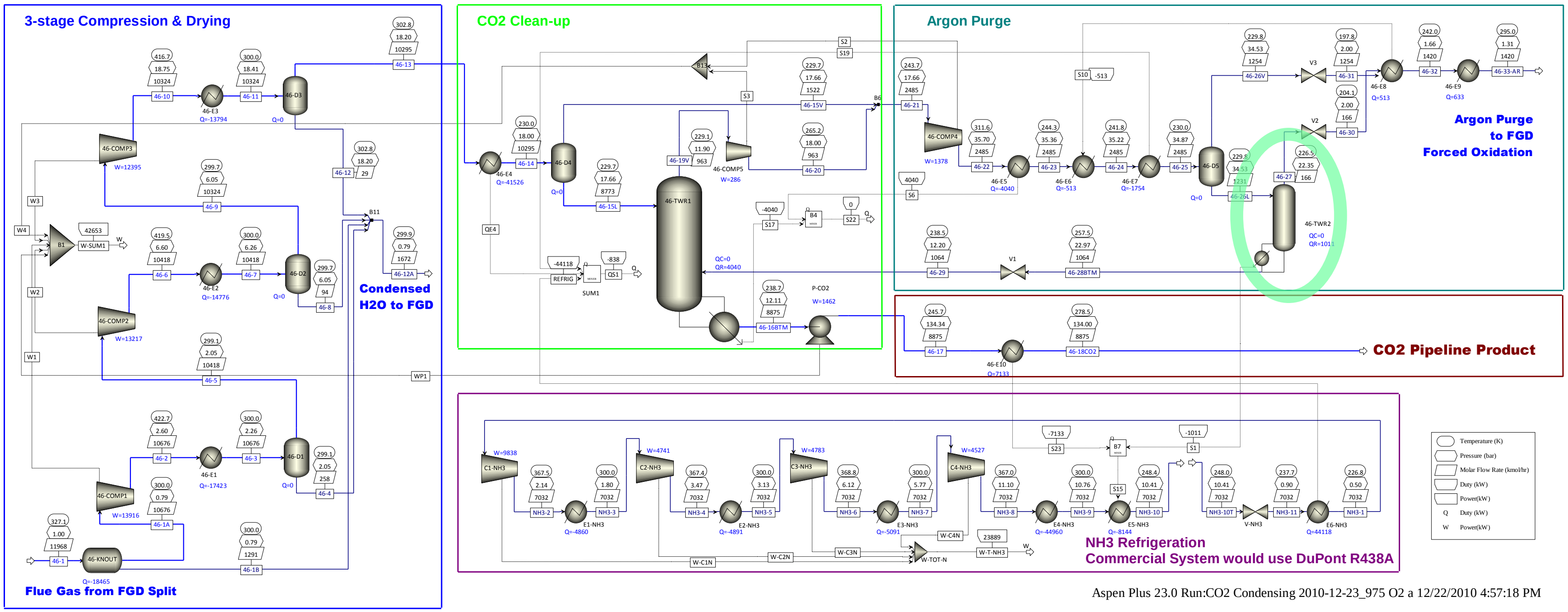
Air Separation Unit — Previously, we used reported values for O_2 purity and trace gases. This was not satisfactory and a Linde-type Cryogenic ASU was developed for 90-99.5% purity **This enhanced the final design of the CO_2 condensing section**

ASPEN NRTL: DEA operates at lower pH, but the steam requirements are higher than MEA



- DEA flow rate was 348% higher than MEA
- DEA Energy demand was ~46% higher than MEA; 614 MW_{heat} vs. 420 MW_{heat}
- There appears to be an issue with MEA loss in the current configuration
- As expected, pH was lower DEA pH=10; MEA pH=11
- O_2 levels were 437 ppm – hence a savings in condensing over Oxyfuels

Oxyfuel CO_2 condensing requires an extra “Argon Purge” and is costlier than Amine CO_2 capture

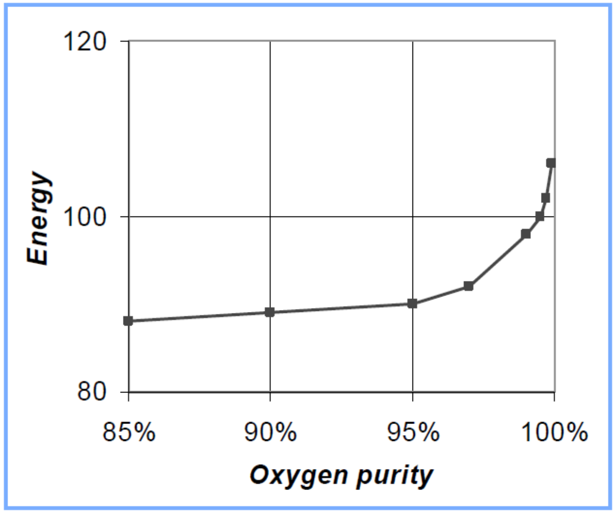


Aspen Plus 23.0 Run:CO2 Condensing 2010-12-23_975 O2 a 12/22/2010 4:57:18 PM

CO_2 Condensing — **Oxyfuels ASPEN 23.0 completed in FY2011, an oxygen clean-up section to prevent CO_2 “slip” was added for the Oxyfuel cases so that pipeline specifications (O_2 = 50 ppm) could be met. An overall look at optimal O_2 was then run.**

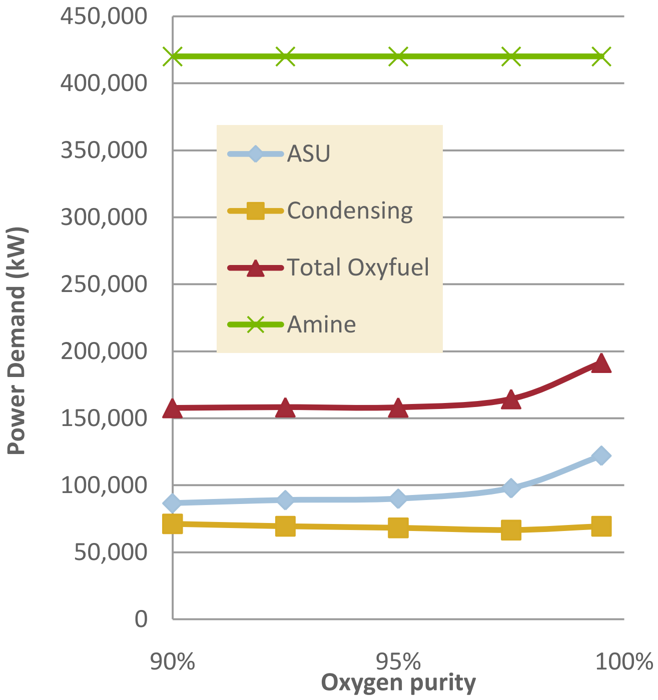
Oxyfuel Cryogenic ASU is the largest system cost—ASU typically uses electricity, but it may also use steam

- Our solution was to model a current Linde ASU system. ASPEN results give both the relative energy use and the gas compositions – critical information for CO_2 liquefaction



A. Darde et al. L'Air Liquide / Energy Procedia 1 (2009) 527–534

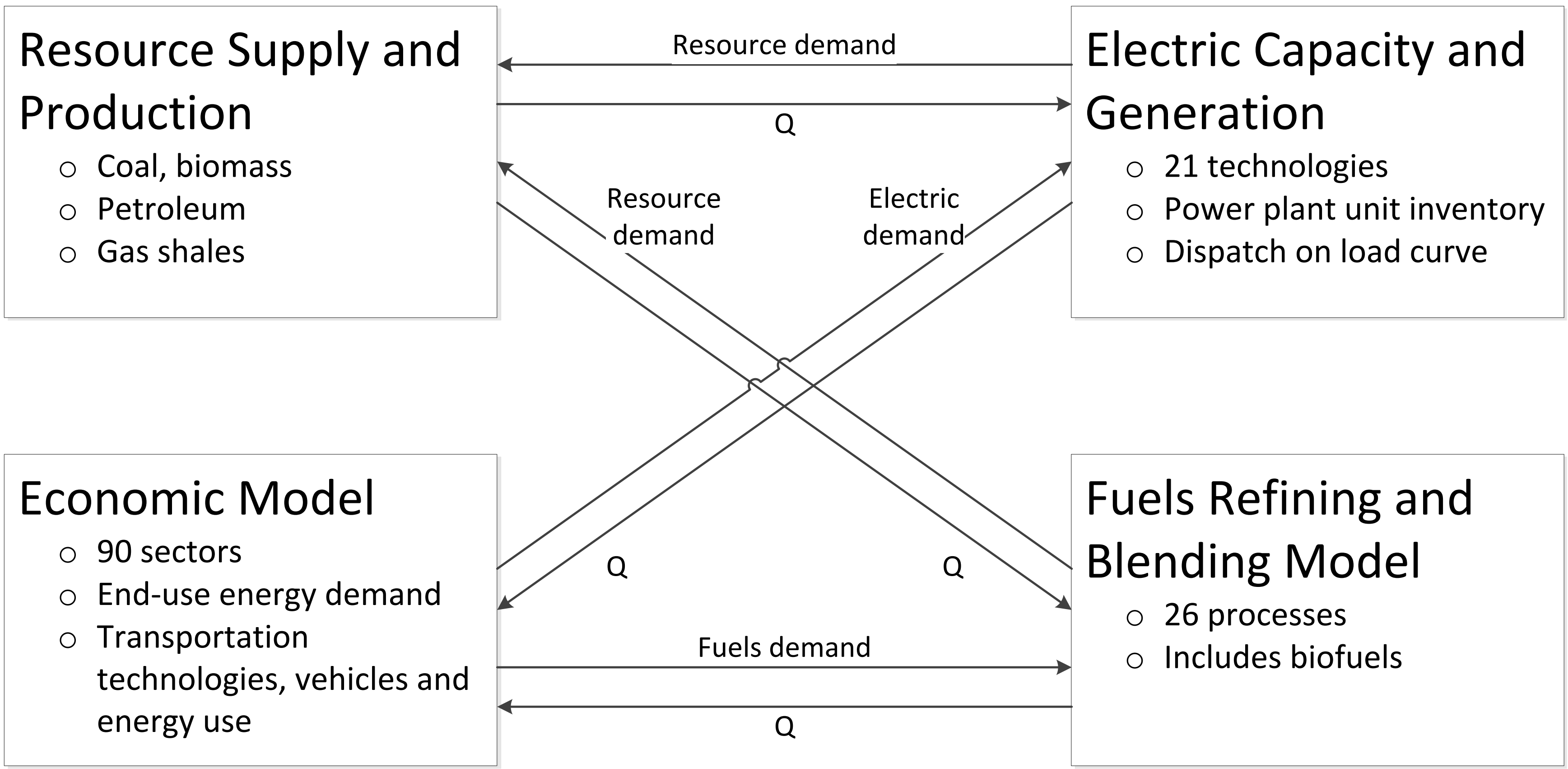
- The Oxyfuel system shows an optimum at ~95% O_2 purity. However, higher purity delivers more pipeline CO_2 that may be a credit.



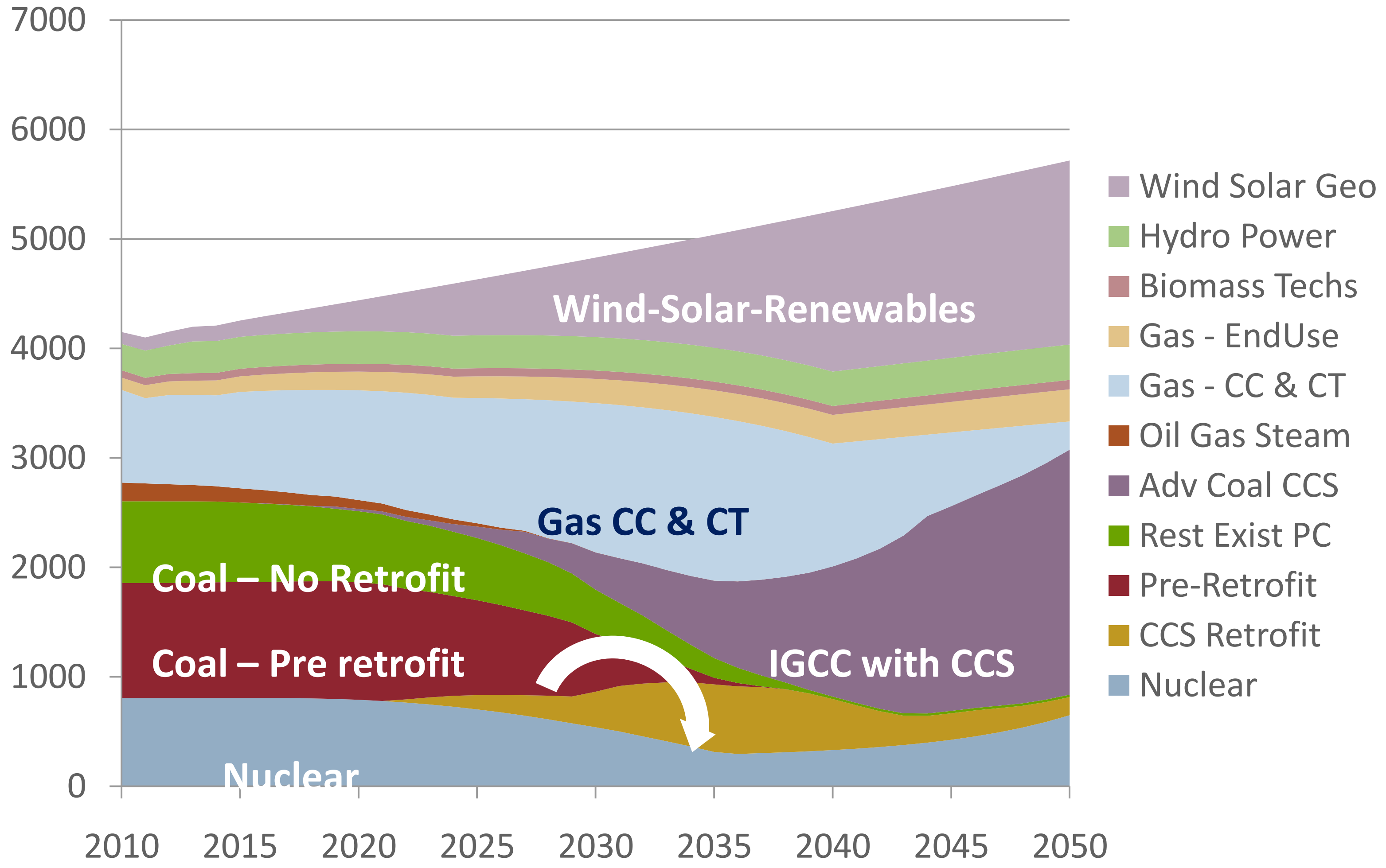
Our Scenario Results Show Need for Existing Plant CCS under a Wide Range of Conditions

- High Gas Shale Production, Slower Electricity Demand Growth (hG-rD)
- High Gas Shale Production, Higher Electricity Demand Growth (hG-HD)
- Lower Gas Shale Production, Slower Electricity Demand Growth (LG-rD)
- Lower Gas Shale Production, Higher Electricity Demand Growth (LG-HD)
- We assume a CO_2 emissions reduction requirement by 2050
- We also assume continued R&D related cost reductions in post-combustion CO_2 capture technology

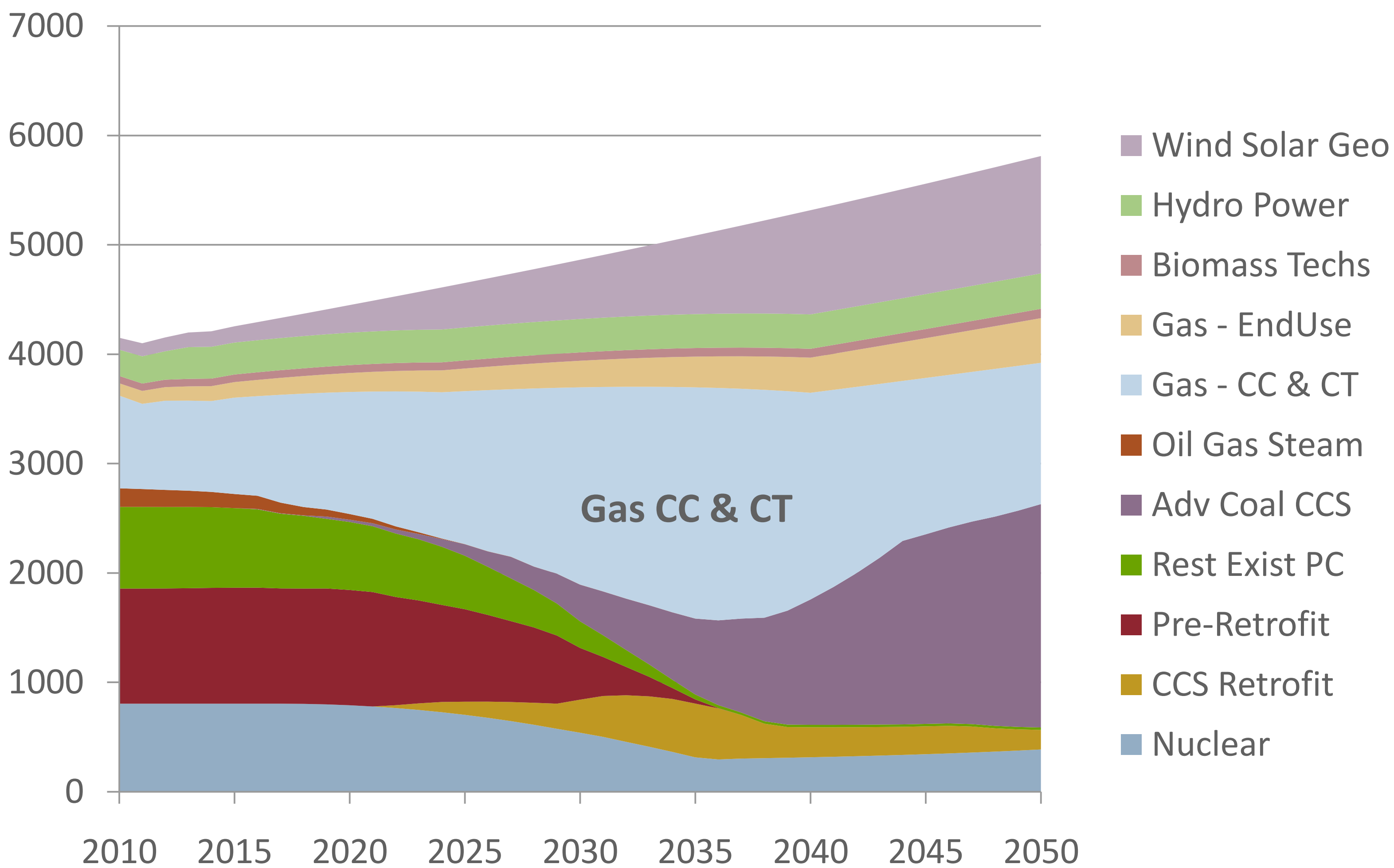
All Modular Integrated Growth Assessment (AMIGA) System *simplified*



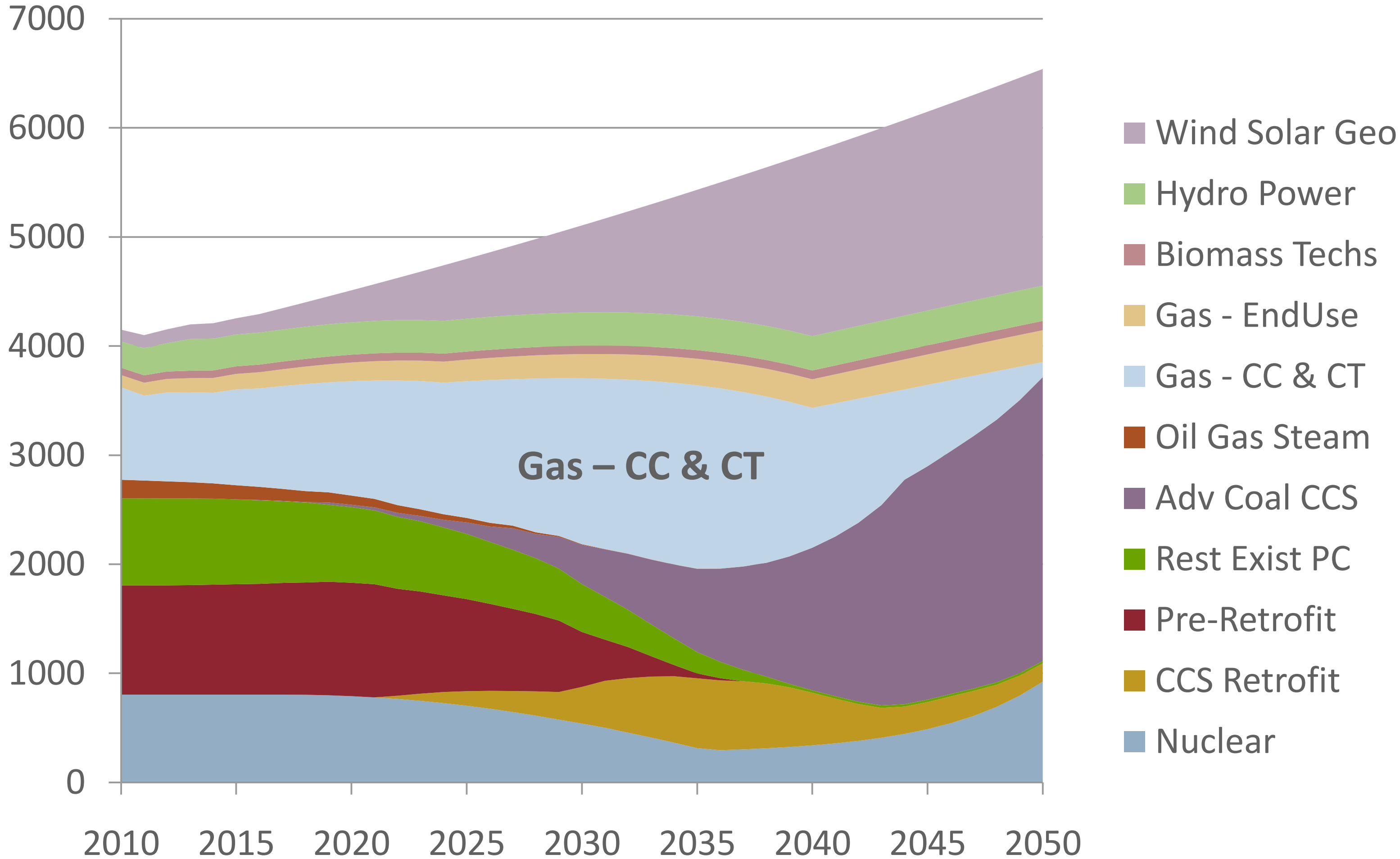
Reference Demand and Reference Gas Shale Scenario – Total Generation (Electric Power Sector & End Use)



High Gas Shale Scenario: Gas Incrementally Displaces Most Other Generation Sources



Higher Electricity Demand due to More Electric Vehicles; Reference Gas Scenario



We find that we need to do about the same number of PC plant retrofits in the High Shale Gas Scenario. The need for this technology is robust, given emission reductions.

- Compare the two shale gas scenarios: High and Low. With more gas …
- Some older, existing coal plants will be repowered with gas, reducing CO_2 emissions.
- Some near-zero generation (i.e., renewables, IGCC with CCS, nuclear) will be displaced on the margin with gas, increasing CO_2 emissions.
- Keeping the amount of CO_2 emissions reduction unchanged, we then need to get about the same amount of CO_2 reduction from retrofitting existing PC plants

Increasing Capacity Factors results in a “rebound” effect on generation. Assume parasitic load of 25%. From example below, (1 - 0.25)*(0.654)/0.544, yielding 10% reduced generation. Further, non-retrofitted units will phase down the load curve and finally retire.

	Low Gas Shale		High Gas Shale	
	RetroUnit	non-retro	RetroUnit	non-retro
Ref Elec Dmd	65.2	51.8	65.4	54.4
High Elec Dmd	67.2	52.5	67.4	54.5

Margins at Which Economic Decisions Apply

- Existing coal-fired units in the unit inventory are sorted by the model in order of highest return for refurbishment and CCS retrofit. NETL studies show great diversity in the population of existing PC units. This is a classic case for obtaining economic efficiency gains through emission trading, relative to command and control regulation.
- Units which are not retrofitted continue to operate until no longer profitable, given the price of electricity and the cost of tradable CO_2 emission allowances.
- New NGCC capacity will enter in the loading order after base-load units with lower variable costs. The (competitive market or regulated) price of electricity must be sufficient to cover full investment costs of new capacity.
- New base-load advanced coal units (e.g., IGCC with CCS) compete with shoulder load NGCC, where IGCC also gets a system cost reduction credit for displacing a portion of higher cost generation, and, through learning, lowering present value cost of future capacity needs (see Hanson references on dynamic programming optimization).

Benefits of the RD&D Program

- We estimate, based on our scenario runs, \$100-\$300 billion in capital expenditures savings, depending on how much CO_2 needs to be reduced and how much retrofit CAPEX can be reduced through RD&D.

- This savings in scarce investment dollars can be applied to other critical needs.

- In all of the scenarios that we ran, coal continues to be a major energy source.

Future Planned Work

- Run additional scenarios showing importance of post-combustion CO_2 capture RD&D (and a null scenario without RD&D showing higher costs and greater capital expenditures)

- Examine impacts of proposed EPA regulations

- Examine regional power pool impacts in US

- Update power plant unit inventory as needed

- Include the energy security benefits of maintaining the existing coal-fired fleet (e.g., reduce oil imports through increased vehicle electrification)

- Examine potential to create jobs in the U.S. by competing in the international CCS market (in other OECD countries and developing world).

References

1. M.G.Shelby, A.Fawcett, E.Smith, D.Hanson, and R.Sands, "Representing technology in CGE Models: A Comparison of SGM and AMIGA for Electricity sector CO_2 Mitigation," *Int. J. Energy Technology and Policy*, Vol 6, No. 4, 2008, pp. 323-342.

2. D.A.Hanson, Y.Kryukov, S.Leyffer, and T.Munson, "Optimal Control Model of Technology Transition," *Int. J. Global Energy Issues*, Vol. 33, Nos. 3-4, 2010, pp.154-175.

3. D.A.Hanson, "Optimizing the Penetration of Advanced Low-Carbon Energy Technologies," USAEE Annual Conference, Houston TX, September 16-19, 2007.